

II. ENVIRONMENTAL SETTING

A. BACKGROUND

Shenandoah National Park (SHEN) is an excellent example of the Blue Ridge/Central Appalachian biome. Figure II-1 shows the park boundary and its division into three management districts. Also indicated are the locations of Federally-designated wilderness areas and air quality monitoring stations. Figure II-2 shows the location of roads, trails, streams, and scenic historic overlooks within the park. SHEN is known for its scenic beauty, outstanding natural features and biota, and historic sites. There have been significant changes in land use prior to and since the establishment of the park. Formerly the location of farmsteads and other industry, land in the park has been allowed to revert to a more natural state since park formation in 1935. However, extensive evidence still remains of the long history of human use of the land.

Significant park features include the following:

1. Skyline Drive. This scenic 165 km drive, shown in Figure II-2, provides the opportunity for views of the Blue Ridge Mountains and surrounding areas. The road was designed and constructed in the 1930s to provide scenic views into the Piedmont Plateau to the east and the Shenandoah Valley to the west. Overlooks were constructed so that motorists could stop at intervals along the drive and enjoy the scenic vistas (Shenandoah National Park 2001).
2. Appalachian National Scenic Trail. The segment of the Appalachian National Scenic Trail that runs through SHEN (shown as the trail that generally parallels Skyline Drive in Figure II-2) is the backbone of the park's trail system.
3. Natural resources. The natural features and biota of the park include well-exposed rock strata of the Appalachians, which is one of the oldest mountain ranges in the world. The park comprises one of the nation's most diverse botanical reserves and diverse wildlife habitats.
4. Wilderness. Congressionally-designated wilderness area within the park is the largest in the Mid-Atlantic states and provides a comparatively accessible opportunity for solitude, study, and experience in a natural area (Shenandoah National Park 1998a).
5. Historic resources. There are over 135 buildings listed on the National Register of Historic Places.

The park is characterized by rounded hills and gently to steeply sloping valleys with near total vegetation coverage. The mountainous ridge of the park grades into the Valley and Ridge Province to the west and the Piedmont Province to the east. The montane-upland Blue Ridge Province extends from Pennsylvania to northern Georgia. Most physiographers apply the Blue

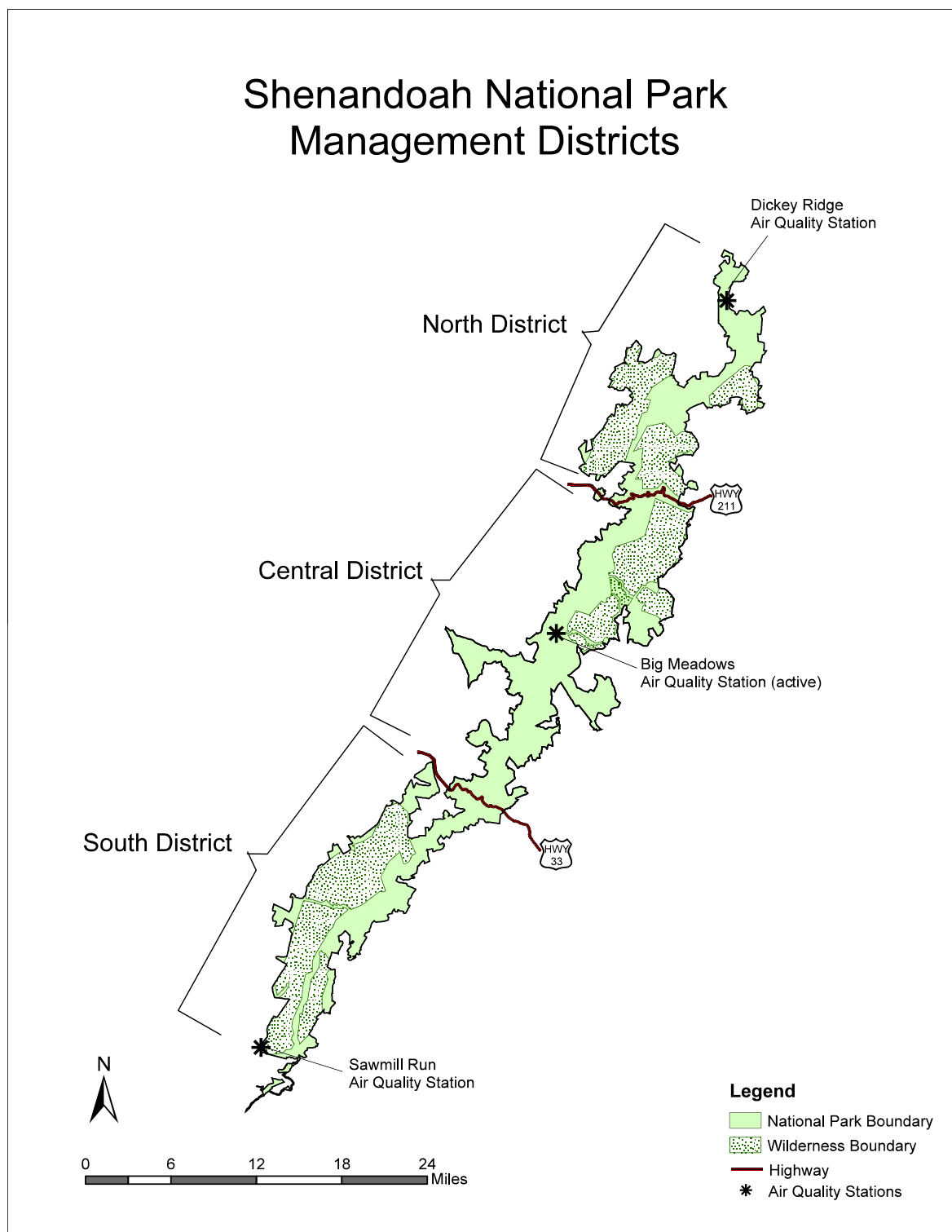


Figure II-1. Shenandoah National Park and division into three management districts. Also shown are the locations of federally-designated wilderness areas and air quality monitoring stations. The air quality stations at Dickey Ridge and Sawmill Run are no longer active.



Figure II-2. Location of roads, trails, streams, and scenic historical overlooks within park boundaries: A) North District, B) Central District, C) South District. Skyline Drive is indicated by a thick red line, extending the length of the park.



Figure II-2. Continued.

Shenandoah National Park - South District

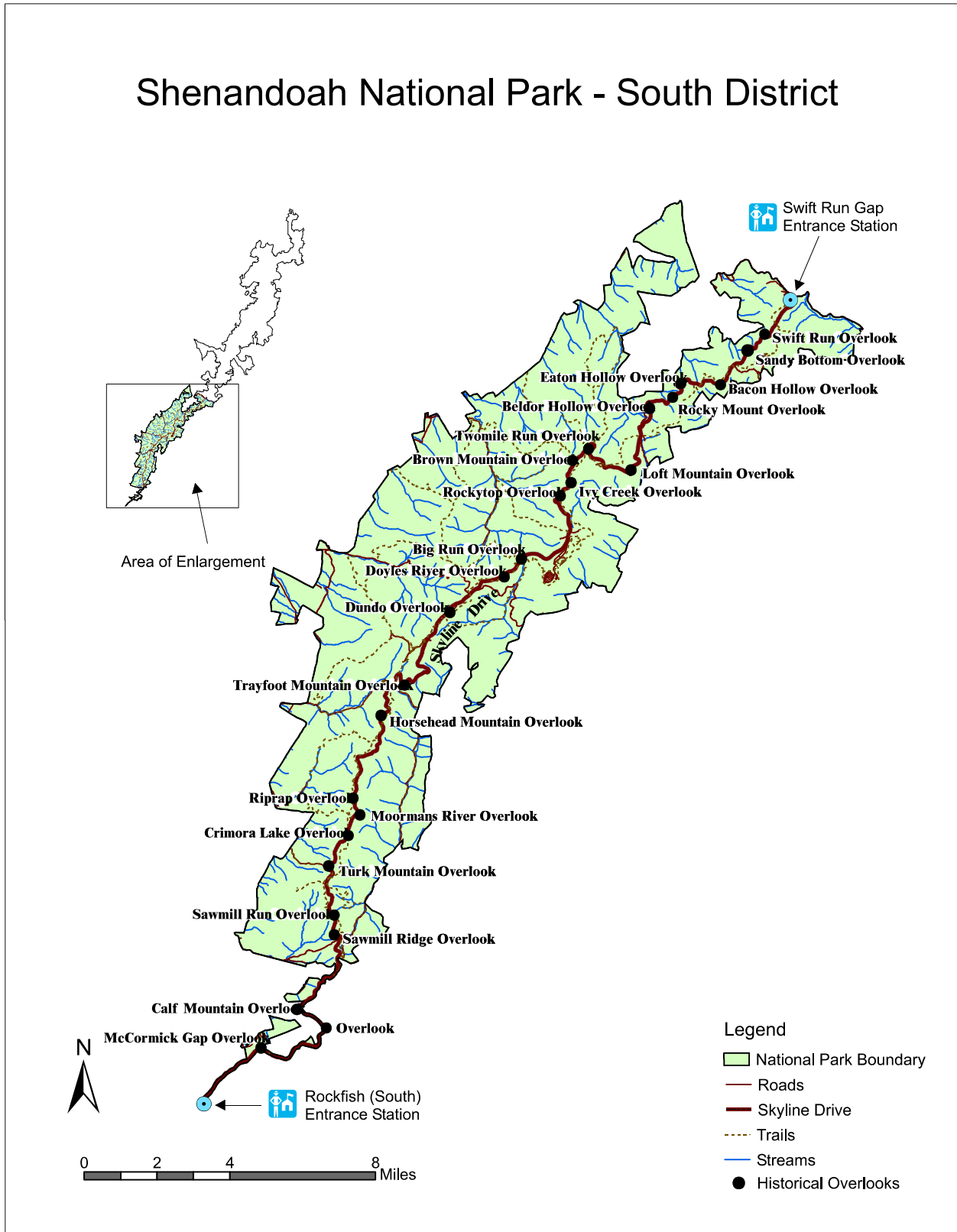


Figure II-2. Continued.

Ridge Province name to all contiguous high mountains underlain by crystalline rocks from south central Pennsylvania to northeastern Georgia, including SHEN and Great Smoky Mountains National Park. The Northern Blue Ridge (Roanoke River to Pennsylvania) is narrow (3-20-km wide overall), whereas the Southern Blue Ridge (Roanoke River to Georgia) widens to nearly 100 km, and increases in height southward. The Blue Ridge rocks are largely resistant to weathering, and streams are mostly of the softwater (low in calcium and magnesium) type.

The Blue Ridge Mountains in which SHEN is located are part of the Appalachian Range. The mountains are comprised of a series of long parallel folds with a single crest of rounded peaks and lower ridges that lies in a northeast to southwest direction. Elevation within the park ranges from 146 m at Front Royal to 1,234 m at Hawksbill Peak. Within the park, there are more than two dozen peaks that are over 900 m high. The land adjacent to the park is changing rapidly from recreational forest, agricultural, and seasonal residential uses to year- round residential use.

As mentioned earlier, interest in preserving areas in the southern Appalachian Mountains began near the turn of the 20th century. In 1924, the Southern Appalachian National Park Committee was appointed by the Secretary of the Interior to investigate the possible existence of sites suitable for the establishment of a national park. The result of the committee's work was an act that was passed in February, 1925 that directed the Secretary of the Interior to determine the boundaries and areas within the Blue Ridge Mountains of Virginia that could be recommended as a new national park. A subsequent act was passed in May, 1926 authorizing SHEN. Its provisions included that the lands could be secured by the United States only by public or private donation, and that the tract include approximately 210,800 ha. The task proved to be quite complicated and costly, and Congress reduced the minimum requirement to 64,735 ha. By 1935, the deeds were ready and the Commonwealth of Virginia donated about 71,400 ha to the Department of the Interior. On July 3, 1936, President Franklin D. Roosevelt dedicated SHEN "to the present and future generations of America for the recreation and re-creation which we shall find here."

SHEN was intended to be a sample of the southern Appalachian portion of primitive America, but approximately half of the forest was cleared at the time of park formation (Reed Engle, National Park Service, pers. comm.). The establishment of the park did, however, offer protection to what remained of Southern Appalachian plants and animals in portions of the park that were still forested, and nature continued its restorative process. The park is now about 95%

forested. Some of the animals that had been greatly reduced or eliminated have returned or have been reintroduced. So complete was the regeneration in the first four decades, that in 1976 nearly 132,370 ha were deemed of suitable primitive character to be included in the National Wilderness Preservation System.

Most homesites were located in the portions of the park that were suitable for farming (Gathright 1976). Farming was rare in the southwest because soils are thin and rocky and slopes are steep (Lynch and Dise 1985).

Logging began in the early 19th century and was most intense during the first two decades of the 20th century. Coupled with the outbreak of chestnut blight and subsequent large-scale tree mortality, logging removed much of the older timber prior to park formation. Mining activities were also conducted throughout the latter half of the 19th century, for iron, manganese, and copper, mainly in the southwestern portions of the park. Logging and farming ceased after the establishment of the park in 1935 (Lynch and Dise 1985).

Several areas of the park have received special recognition due to the significance of natural and cultural resources. For example, in 1985, the Shaver Hollow watershed was designated as the first Research Natural Area in a National Park Service (NPS) unit in eastern deciduous forest. It serves as a focal area for intensive watershed research within the park. In addition, in 1996 Skyline Drive and associated developed areas at Simmons Gap, Big Meadows, Piney River, Pinnacles, Dickey Ridge, and Park Headquarters were listed on the National Register of Historical Places.

SHEN has become significant for the following reasons:

- The park provides a traditional national park experience in the east.
- It is close to large metropolitan populations, providing relatively good accessibility to millions of citizens.
- Establishment of this park represented a conscious change in human use of the land. With ongoing vegetation recovery, the park has become a sizeable forested area, with large areas of designated wilderness.
- It includes developed areas that are listed on, or determined to be eligible for, the National Register or as national historical landmarks.
- The park includes the longest segment of the Appalachian National Scenic Trail that occurs in a national park.

Central to the significance of the park are the rural agricultural landscapes that surround it. These lands are the primary components of the vistas from Skyline Drive. They are additional components of the ecosystem that supports park wildlife and other values that are significant to the purposes for which the park was initially established. There are large blocks of undeveloped natural uplands, which contrast with the valley mosaic of privately owned farmland, forests, and settled areas. The wilderness contained in the park is the largest in Virginia and provides comparatively accessible opportunity for solitude, study, and experience in a natural area that has been allowed to revert to wilderness from past human land use.

B. CLIMATE

The Atlantic Ocean, and in particular the Gulf Stream, plays an important role in Virginia's precipitation regime. Winter storms generally track from the west to the east, and in the vicinity of the east coast move to the northeast paralleling the coast and the Gulf Stream. This shift to the northeast results partly from the tendency of storms to follow the boundary between the cold land and the warm Gulf Stream. When sufficiently cold air comes into Virginia from the west and the northwest, frontal storms can bring heavy snowfall. Thunderstorms occur in all months of the year, but are most common during summer. Precipitation is well distributed throughout the year, with a maximum in September and minimum in February. Storms and high runoff conditions can occur year-round at SHEN. Most locations receive 100 to 150 cm of precipitation per year. South to southwest winds predominate, with secondary maximum frequency from the north. Lower elevation areas of the park experience modified continental climate, with mild winters and warm, humid summers. The mean annual temperature in the lowland area at Luray averages 12 °C, and average annual precipitation is 91 cm, with about 43 cm of snow.

Higher elevation areas of the park experience winters that are moderately cold and summers that are relatively cool. The mean annual temperature at Big Meadows averages about 9 °C. Mean maximum daily temperatures in July average about 6 °C cooler at Big Meadows than in the lowland areas of the park. Temperatures in January range from about -7° to 4° C and in July from about 14° to 24° C. The average annual precipitation at Big Meadows is 132 cm, which includes about 94 cm of snow. Snow and ice are common in winter, but they usually melt quickly, leaving the ground bare. Occasional major snow or ice storms can cause considerable damage to the trees within the park.

Baseflow stream discharge is lowest in summer and early fall, reflecting evapotranspiration by terrestrial vegetation; highest baseflow occurs in winter and early spring. High discharges associated with storms can occur at anytime of year. For streams within forested mountain catchments, annual water yield is often 40-70% (annual discharge/annual precipitation; SAMAB 1996).

C. SCENERY

In its report to Congress, the Southern Appalachian National Park Committee highlighted the importance of scenery to the purpose and national significance of SHEN. The committee identified a possible sky-line drive as the greatest single feature of the area that was to become SHEN, and noted that the Blue Ridge mountains of northern Virginia met aesthetic requirements including but not limited to... “mountain scenery with inspiring perspectives and delightful details”...that contains...“forests, shrubs and flowers, and mountain streams, with picturesque cascades and waterfalls overhung with foliage...”. The 163-km (105-mi) Skyline Drive was constructed by the Civilian Conservation Corps from 1931 to 1939. Most of the 157-km (101-mi) segment of the Appalachian National Scenic Trail found within the park was constructed by the Potomac Appalachian Trail Club in the 1930s. Today, the Appalachian National Scenic Trail forms the backbone for the park’s extensive trails network totaling about 800 km (500 mi). Since the park’s creation in 1935, millions of visitors have enjoyed the views from numerous vistas within the park.

SHEN has a unique blend of exceptional scenic beauty, outstanding natural features, diverse deciduous forests, wildlife, and historic sites in a mountain setting. Scenic views can be experienced by driving or cycling the Skyline Drive, walking the Appalachian National Scenic Trail and related trails, and experiencing the backcountry wilderness areas. The Drive’s historic overlooks and the Appalachian National Scenic Trail afford scenic views of the pastoral Shenandoah Valley to the west or the Piedmont Plateau to the east (occasionally both) on clear days. The park is a popular destination to view fall colors in October. Old Rag Mountain in the Central District is one of the most popular hikes in the park. Rising from the edge of the Piedmont, its pinnacle of giant granite boulders, with challenging rock scrambles, makes this destination a unique regional attraction that provides 360-degree views. Visitors also enjoy numerous short hikes to picturesque waterfalls (Figure II-3).



Figure II-3. Examples of outstanding scenery within SHEN.

D. SURFACE WATERS

High gradient is a chief feature of high-elevation streams in Virginia. Pools are interspersed with riffles, rapids, cascades and falls. Stream bottoms are chiefly comprised of large gravel, rubble, boulder and bedrock. Streams are cool or even cold in summer, typically clear, and rain-caused turbidity clears rapidly (Jenkins and Burkhead 1993). Patrick (1996) described typical Mid-Atlantic high-gradient mountain streams as heavily shaded in summer, having very few macrophytes and filamentous algae, with main primary productivity by diatoms. This description is also reflective of the mainly first-, second- and third-order streams of SHEN. Wallace et al. (1992) defined high-gradient streams as those with longitudinal gradients exceeding 0.15% slope (1.5 m per km), consistent with other definitions. Such streams typically occur between 330 and 2000 m above sea level. There are many such streams within the Valley and Ridge and Blue Ridge physiographic provinces, as well as in the Piedmont. The Blue Ridge (in which SHEN is located) is covered in dense deciduous and coniferous forests, with steep slopes up to 30%. High-gradient streams of the Blue Ridge are typically dendritic; stream density may be as high as 6.2 km/km². Streams in adjacent valleys may have different slopes and stream chemistry due to differences in bedrock composition.

Although acidic deposition is ubiquitous regionally, its interaction with local geological formations determines where effects on stream chemistry will occur. Stream concentrations of important ions (Ca²⁺, Mg²⁺, K⁺, Na⁺, Cl⁻, NO₃⁻, SO₄²⁻) are usually low in regional mountain streams. Concentrations of NO₃⁻, NH₄⁺, and PO₄ may be very low (0.001-0.004 mg/L as nitrogen or phosphorus for each) in forested streams draining crystalline watersheds. Stream pH typically decreases with increasing elevation, as is the case within SHEN (Bulger et al. 1999).

There are 42 watershed basins on the west side of SHEN and 28 watershed basins on the east. In many places, the streams drop over ledges, creating waterfalls up to 28 m high. There are about 72 perennial streams in the park (Figure II-2), and over 50 of those contain native brook trout (*Salvelinus fontinalis*; Shenandoah National Park 1998b). Almost all of the streams in the park are at least largely headwater streams that drain into three major river basins, the Potomac River to the west and the Rappahannock and James Rivers to the east. This headwater status increases their potential sensitivity to adverse impacts from acidic deposition for a variety of reasons. In general, headwater streams are more likely than lower-elevation streams to be underlain by relatively homogeneous bedrock and soils, in many cases having low base cation supply. In addition, higher-elevation watershed areas are more likely to have shallow soils,

exhibit greater base cation leaching losses due to higher precipitation, and receive smaller base cation contributions from weathering due to colder temperatures.

Variation in bedrock geology plays a major role in determining variation in forest cover and streamwater chemistry within the park. The observed relationships between geology and water chemistry form the basis for relating intensively-studied watersheds in a hierarchical fashion to a geographically-extensive landscape coverage within the park and surrounding areas.

Loss of streamwater acid neutralizing capacity (ANC) in forested streams draining watersheds with crystalline or siliciclastic bedrock in response to acidic deposition occurs when concentrations of strong-acid anions (SO_4^{2-} and NO_3^-) increase relative to concentrations of base cations (Ca^{2+} , Mg^{2+} , K^+ , Na^+). If surface water ANC is reduced to sufficiently low values, acidity may increase, as indicated by a depression in pH, to a range associated with adverse effects on fish and other aquatic life (Baker and Christensen 1991).

Acidic deposition can contribute to both chronic (long-term) and episodic (short-term) decline in streamwater ANC. The degree to which acidic deposition results in chronic loss of ANC in streams within SHEN depends mainly upon two watershed processes associated with acid-base status: 1) acid anion retention in watershed soils; and 2) base-cation release from watershed soils and rocks (Elwood 1991, Church et al. 1992). The degree to which acidic deposition results in episodic loss of ANC in surface water depends largely upon the hydrologic flow paths associated with high-runoff conditions (Turner et al. 1990, Wigington et al. 1990).

E. AQUATIC BIOTA

1. Fish

Table II-1 lists the species of fish most commonly found in SHEN. Rows 1-5 list the stream names, the SHEN district (North, Central, or South) where streams are located, the drainage (Potomac, James or Rappahannock Rivers) into which each stream flows, the side (East or West facing slope) where streams are located, and the total number of fish species recorded to date in each stream. There are a small number of additional fishless streams in the park. The next 34 rows record the presence of each of the fish species in each stream.

[illegible]

Table II-1. Continued.

		Description	District	Drainage	Side of Park
Abundance		Species found at intervals of five years or greater within the park.	N=North	J=James	E=East
R=Rarely encountered		Species with less than ten (<10) known populations in the park.	C=Central	P=Potomac	W=West
U=Uncommon		Species with between ten and twenty (10 to 20) known populations in the park.	S=South	R=Rappahannock	
C=Common		Species with greater than twenty (>20) known populations in the park.			
=Abundant					
Bass, Rock	U				
Bass, Smallmouth	U				
Bass, Largemouth	U				
Sunfish, Redbreast	U				
Pumpkinseed	U				
Darter, Greenside	R				
Darter, Johnny	R				
Darter, Tesselated	U				
Darter, Fantail	C				

Acidification is a conspicuous threat to three trout species in the region: brook trout, brown trout, and rainbow trout. Although brown and rainbow trout are found within SHEN, brook trout predominate. Of the three, native brook trout is the most acid tolerant, brown trout introduced from Europe is intermediate in acid tolerance, and rainbow trout introduced from the western United States is most sensitive. A recent survey (SAMAB 1996) concluded that trout populations are regarded by residents as among the region's most valuable aquatic natural resources, and trout populations and trout habitat are major concerns to the public in the southern Appalachians. Sources of concern generally fall into three categories: 1) fisheries for native brook trout and introduced rainbow and brown trout; 2) "existence value" for brook trout, regarded as a beautiful and intrinsically valuable native species; and 3) the presence of trout as indicators of high water quality.

2. Invertebrates

Benthic macroinvertebrates have been monitored in SHEN streams since 1986 as part of the Long-Term Ecological Monitoring System (LTEMs). They have several characteristics that make them particularly useful for biomonitoring (Moeykens and Voshell, 2002):

- Benthic macroinvertebrates occur in almost all types of freshwater habitats.
- There are many different taxa which include a wide range of sensitivity to environmental stress.
- They have mostly sedentary habits and are therefore likely to be exposed to ambient pollution or environmental stress.
- The duration of their life histories are sufficiently long such that they will likely be exposed to the environmental stress that is present, and the community will not recover so quickly that the impact will go undetected.
- Sampling the benthic macroinvertebrate assemblage is relatively simple and does not require complicated equipment or great effort.
- Taxonomic identification is almost always easy to the family level and usually easy to the genus level.

Since 1986, the benthic macroinvertebrate community at 17 core LTEMs sites in SHEN has been sampled at least once per year, and in 1995 SHEN personnel began to sample other sites with the goal of eventually sampling every permanent stream within park boundaries (Moeykens and Voshell, 2002). The sampling techniques and LTEMs protocols were described by Voshell

and Hiner (1990). The data summarized here cover samples taken between June 1988 and June 2000 (12 years) and include 43 streams.

There are five phyla of benthic macroinvertebrates represented in the samples from SHEN streams: Annelida (principally Oligochaeta), Arthropoda (including Insecta, Arachnida, and Crustacea), Mollusca (including Bivalvia and Gastropoda), Nematoda, and Platyhelminthes (principally Turbellaria).

Of particular importance to the ecology of the streams in the park are the aquatic insects (Class Insecta). There are nine orders of aquatic insects present in the SHEN LTEMs samples: Coleoptera, Collembola, Diptera, Ephemeroptera (mayflies), Hemiptera, Megaloptera, Odonata, Plecoptera (stoneflies), and Trichoptera (caddisflies). From these nine orders of aquatic insects, 79 families have been collected in SHEN streams. Not all families are present in each stream. The total number of insect families found in a given stream during the sampling period varies from 21 to 56 (Table II-2).

Some aquatic insect families are represented in only a few streams and some families are found in all streams (Table II-3). Nine families (Helicopsychidae, Ptychopteridae, Stratiomyiidae, Potamanthidae, Siplonuridae, Belostomatidae, Notonectidae, Haliplidae, and Helophoridae) have each been found in only one stream within SHEN (not all in the same stream). On the other hand, nine other families (Hydropsychidae, Chironomidae, Tipulidae, Baetidae, Ephemerellidae, Heptageniidae, Leuctridae, Perlodidae, and Psephenidae) have been found in all 43 streams that have been sampled.

F. GEOLOGY AND SOILS

The geology of the area in and around SHEN was formed in part as a result of plate tectonics. There were four collisional events involving eastern North America which contributed to the formation of the mountains and metamorphism of the existing rocks. There have also been two rifting events, which caused volcanic eruptions and the opening of ocean basins. The first resulted in extrusion of the Catoctin volcanic rocks about 570 million years ago. The second, which occurred about 200 million years ago, resulted in the opening of the Atlantic Ocean basin (Badger 1999).

The geology of the park represents one of its most outstanding natural resources. Exposed formations of the Blue Ridge Mountains are among the oldest in North America. The geologic history of the park has been the subject of frequent investigations by geologists and university

Table II-2. Total number of invertebrate families of each order present in SHEN streams (Phylum Arthropoda, Class Insecta).										
Stream Name	Order Coleoptera	Order Collembola	Order Diptera	Order Ephemeroptera	Order Hemiptera	Order Megaloptera	Order Odonata	Order Plecoptera	Order Trichoptera	Total Families in Stream
Big Meadows Effluent	1	0	5	5	0	0	1	6	7	25
Big Run	3	1	10	5	2	1	1	8	11	42
Bolton Branch	4	0	7	4	0	2	1	7	7	32
Broad Hollow Run	2	1	8	6	2	0	1	7	10	37
Brokenback Run	3	1	7	6	1	1	2	7	9	37
Cedar Run	2	0	5	5	1	0	0	7	8	28
Deep Run	2	0	5	5	1	1	0	6	7	27
Doyles River	2	0	6	4	0	0	1	6	7	26
Dry Run, N. Fork	2	1	8	6	3	2	1	8	14	45
Eppert Hollow Run	1	0	3	4	1	1	1	8	6	25
Fultz Run	2	0	6	4	1	1	1	6	6	27
Hannah Run	2	0	6	4	1	1	1	6	5	26
Happy Creek	3	0	5	4	0	1	0	5	5	23
Hawksbill Creek (Beldor)	2	0	5	6	1	1	1	7	5	28
Hazel River	4	1	11	9	2	2	2	9	16	56
Hughes River	2	0	8	6	2	1	0	8	8	35
Ivy Creek	3	1	8	7	2	1	0	7	9	38
Jeremy's Run	3	1	8	8	2	2	1	9	13	47
Keyser Run	2	0	3	4	2	0	0	6	4	21
Land's Run	3	1	8	7	2	2	1	8	14	46
Little Hawksbill Creek	2	0	7	4	1	1	1	6	8	30
Lower Lewis Run	2	1	6	6	2	1	1	7	12	38
Madison Run	4	1	7	5	2	1	1	9	11	41
Meadow Run	2	1	6	7	3	1	1	8	11	40
Moormans River, N. Fork	3	1	9	7	2	1	1	9	12	45
Naked Creek, E. Branch	2	0	6	6	1	1	1	7	7	31
Naked Creek, W. Branch	3	0	6	5	0	0	0	7	7	28
Onemile Run	2	1	6	6	3	2	1	8	11	40
Overall Run	1	0	5	5	0	0	0	5	6	22
Paine Run	4	1	9	5	4	2	2	9	14	50
Pass Run	3	0	6	7	0	2	1	9	10	38
Piney River	6	1	10	8	3	2	2	9	15	56
Rapidan River	4	0	9	7	2	1	1	8	12	44
Rose River	4	1	10	7	2	2	2	9	16	53
Sawmill Run	3	0	7	6	2	1	1	9	10	39
South River	2	0	6	5	0	0	0	7	8	28
Staunton River	4	1	12	7	2	2	1	9	16	54
Swift Run	2	0	8	6	0	0	2	6	7	31
Thornton River, N. Fork	2	1	5	5	1	1	0	6	8	29
Thornton River, S. Fork	3	0	9	8	1	1	1	8	12	43
Twomile Run	5	1	8	6	3	2	2	9	14	50
Whiteoak Canyon Run	6	1	11	7	2	2	1	9	14	53
Whiteoak Run	5	1	6	5	2	1	1	8	8	37

Stream Name	Families of Order Trichoptera																
	Brachycentridae	Glossosomatidae	Goeridae	Helicopsychidae	Hydropsychidae	Hydroptilidae	Lepidostomatidae	Leptoceridae	Limnephilidae	Molannidae	Odontoceridae	Philopotamidae	Polycentropodidae	Psychomyiidae	Rhyacophilidae	Sericostomatidae	Uenoidae
Big Meadows Effluent					X		X		X		X			X	X		X
Big Run	X	X		X	X	X	X	X	X			X	X				X
Bolton Branch		X			X	X						X	X		X		X
Broad Hollow Run		X			X		X		X	X		X	X	X	X		X
Brokenback Run		X			X		X		X	X	X	X			X		X
Cedar Run	X	X			X		X		X			X	X				X
Deep Run		X			X		X					X	X		X		X
Doyles River		X			X				X			X	X		X		X
Dry Run, N. Fork	X	X	X		X	X	X		X	X	X	X	X	X	X		X
Eppert Hollow Run	X				X				X			X			X		X
Fultz Run		X			X				X			X	X				X
Hannah Run	X	X			X							X	X				
Happy Creek		X			X							X	X	X			
Hawksbill Creek (Beldor)					X	X						X	X				X
Hazel River	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
Hughes River	X	X			X				X			X	X		X		X
Ivy Creek					X	X	X	X	X			X	X		X		X
Jeremy's Run	X	X			X	X	X		X	X		X	X	X	X	X	X
Keyser Run					X				X			X			X		
Land's Run	X	X	X		X		X	X	X	X	X	X	X	X	X		X
Little Hawksbill Creek	X	X			X		X		X			X	X		X		
Lower Lewis Run	X	X			X	X	X	X	X		X	X	X		X		X
Madison Run	X	X			X	X	X		X		X	X	X		X		X
Meadow Run	X	X			X	X	X	X	X			X	X		X		X
Moormans River, N. Fork	X	X			X	X	X		X	X	X	X	X		X		X
Naked Creek, E. Branch		X			X				X			X	X		X		X
Naked Creek, W. Branch	X	X			X				X			X	X		X		
Onemile Run	X	X			X	X	X		X	X		X	X		X		X
Overall Run					X	X	X		X			X			X		
Paine Run	X	X			X	X	X	X	X	X	X	X	X	X	X		X
Pass Run		X			X	X	X		X			X	X	X	X		X
Piney River	X	X	X		X	X	X	X	X	X	X	X	X	X	X		X
Rapidan River	X	X			X	X	X		X	X	X	X	X		X		X
Rose River	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
Sawmill Run	X	X			X	X	X			X		X	X		X		X
South River		X			X	X	X		X			X			X		X
Staunton River	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
Swift Run	X	X			X							X	X		X		X
Thornton River, N. Fork		X			X		X		X			X	X		X		X
Thornton River, S. Fork	X	X			X	X	X	X	X		X	X	X		X		X
Twomile Run	X	X			X	X	X	X	X	X	X	X	X	X	X		X
Whiteoak Canyon Run	X	X			X	X	X	X	X	X	X	X	X	X	X		X
Whiteoak Run		X			X	X	X		X			X	X		X		
Summary	26	37	6	1	43	25	31	13	36	16	16	42	37	14	37	4	36

Table II-3 Continued.															
Stream Name	Families of Order Diptera														
	Athericidae	Blephariceridae	Ceratopogonidae	Chironomidae	Culicidae	Dixidae	Empididae	Ephydriidae	Muscidae	Psychodidae	Ptychopteridae	Simuliidae	Stratiomyidae	Tabanidae	Tipulidae
Big Meadows Effluent				X			X		X			X			X
Big Run		X	X	X	X	X	X		X			X		X	X
Bolton Branch		X	X	X		X	X					X			X
Broad Hollow Run		X	X	X		X	X		X			X			X
Brokenback Run	X	X	X	X		X						X			X
Cedar Run		X	X	X								X			X
Deep Run			X	X			X					X			X
Doyles River		X	X	X		X						X			X
Dry Run, N. Fork		X	X	X		X	X					X		X	X
Eppert Hollow Run			X	X											X
Fultz Run			X	X		X	X					X			X
Hannah Run		X		X		X	X					X			X
Happy Creek		X		X			X					X			X
Hawksbill Creek (Beldor)		X	X	X								X			X
Hazel River	X	X	X	X		X	X		X	X		X		X	X
Hughes River	X	X	X	X		X	X					X			X
Ivy Creek		X	X	X		X	X		X			X			X
Jeremy's Run		X	X	X		X	X	X				X			X
Keyser Run			X	X											X
Land's Run		X	X	X		X	X					X		X	X
Little Hawksbill Creek	X	X	X	X			X					X			X
Lower Lewis Run			X	X		X	X					X			X
Madison Run		X	X	X		X	X					X			X
Meadow Run			X	X			X		X			X			X
Moormans River, N. Fork	X	X	X	X		X	X					X		X	X
Naked Creek, E. Branch		X	X	X			X					X			X
Naked Creek, W. Branch		X		X		X	X					X			X
Onemile Run		X	X	X			X					X			X
Overall Run		X	X	X								X			X
Paine Run		X	X	X		X	X		X			X		X	X
Pass Run		X	X	X			X					X			X
Piney River		X	X	X		X	X			X		X	X	X	X
Rapidan River	X	X	X	X			X	X				X		X	X
Rose River	X	X	X	X		X	X			X		X		X	X
Sawmill Run			X	X	X	X	X					X			X
South River		X	X	X			X					X			X
Staunton River	X	X	X	X	X	X	X		X	X	X	X			X
Swift Run	X	X	X	X		X	X					X			X
Thornton River, N. Fork		X	X	X								X			X
Thornton River, S. Fork	X	X	X	X		X	X					X		X	X
Twomile Run		X	X	X		X	X		X			X			X
Whiteoak Canyon Run	X	X	X	X	X	X	X		X	X		X			X
Whiteoak Run		X	X	X		X						X			X
Summary	11	35	39	43	4	27	34	2	10	5	1	41	1	10	43

Stream Name	Families of Order Ephemeroptera											Families of Order Hemiptera				
	Ameletidae	Baetidae	Baetiscidae	Caenidae	Ephemereilidae	Ephemeridae	Heptageniidae	Isonychiidae	Leptophlebiidae	Potamanthidae	Siphonuridae	Belostomatidae	Gerridae	Mesoveliidae	Notonectidae	Veliidae
Big Meadows Effluent	X	X			X		X		X							
Big Run	X	X			X		X		X				X			X
Bolton Branch		X			X	X	X									
Broad Hollow Run	X	X			X	X	X		X				X			X
Brokenback Run	X	X			X	X	X		X				X			
Cedar Run	X	X			X		X		X				X			
Deep Run	X	X			X		X		X				X			
Doyles River		X			X		X		X							
Dry Run, N. Fork	X	X			X		X	X	X				X	X		X
Eppert Hollow Run		X			X		X		X							X
Fultz Run		X			X		X		X				X			
Hannah Run		X			X		X		X				X			
Happy Creek		X			X		X	X								
Hawksbill Creek (Beldor)		X			X	X	X	X	X				X			
Hazel River	X	X	X	X	X	X	X	X	X				X			X
Hughes River	X	X			X		X	X	X				X			X
Ivy Creek	X	X			X	X	X	X	X				X			X
Jeremy's Run	X	X		X	X	X	X	X	X				X			X
Keyser Run		X			X		X		X				X			X
Land's Run	X	X			X	X	X		X	X			X			X
Little Hawksbill Creek		X			X		X		X				X			
Lower Lewis Run	X	X			X		X	X	X				X			X
Madison Run	X	X			X		X		X				X			X
Meadow Run	X	X			X		X	X	X		X		X	X		X
Moormans River, N. Fork	X	X			X	X	X	X	X				X			X
Naked Creek, E. Branch		X			X	X	X	X	X				X			
Naked Creek, W. Branch		X			X		X	X	X							
Onemile Run	X	X			X		X	X	X				X	X		X
Overall Run	X	X			X		X		X							
Paine Run	X	X			X		X		X			X	X		X	X
Pass Run		X	X		X	X	X	X	X							
Piney River	X	X	X		X	X	X	X	X				X	X		X
Rapidan River	X	X			X	X	X	X	X				X			X
Rose River	X	X			X	X	X	X	X				X			X
Sawmill Run	X	X			X		X	X	X				X			X
South River	X	X			X		X		X							
Staunton River	X	X			X	X	X	X	X				X			X
Swift Run	X	X			X		X	X	X							
Thornton River, N. Fork		X			X		X	X	X				X			
Thornton River, S. Fork	X	X	X		X	X	X	X	X				X			
Twomile Run	X	X			X		X	X	X				X	X		X
Whiteoak Canyon Run	X	X			X	X	X	X	X				X			X
Whiteoak Run	X	X			X		X		X				X			X
Summary	30	43	4	2	43	17	43	24	41	1	1	1	33	5	1	24

Table II-3. Continued.													
Stream Name	Families of Order												
	Plecoptera									Megaloptera		Odonata	
	Capniidae	Chloroperlidae	Leuctridae	Nemouridae	Peltoperlidae	Perlidae	Perlodidae	Pteronarcyidae	Taeniopterygidae	Corydalidae	Sialidae	Anisoptera	Zygoptera
Big Meadows Effluent		X	X	X	X		X		X			X	
Big Run		X	X	X	X	X	X	X	X	X		X	
Bolton Branch		X	X	X	X	X	X	X		X	X	X	
Broad Hollow Run		X	X	X	X	X	X	X				X	
Brokenback Run	X	X	X		X	X	X	X		X		X	X
Cedar Run	X	X	X		X	X	X	X					
Deep Run		X	X	X	X	X	X			X			
Doyles River		X	X		X	X	X	X				X	
Dry Run, N. Fork	X	X	X	X	X	X	X	X		X	X	X	
Eppert Hollow Run	X	X	X	X	X	X	X	X			X	X	
Fultz Run		X	X		X	X	X	X		X		X	
Hannah Run		X	X	X	X	X	X			X		X	
Happy Creek			X	X	X		X		X	X			
Hawksbill Creek (Beldor)		X	X	X	X	X	X	X		X		X	
Hazel River	X	X	X	X	X	X	X	X	X	X	X	X	X
Hughes River	X	X	X	X	X	X	X	X		X			
Ivy Creek		X	X	X	X	X	X	X		X			
Jeremy's Run	X	X	X	X	X	X	X	X	X	X	X	X	
Keyser Run	X	X	X			X	X	X					
Land's Run	X	X	X	X	X	X	X	X		X	X	X	
Little Hawksbill Creek		X	X		X	X	X	X		X		X	
Lower Lewis Run		X	X	X	X	X	X	X		X		X	
Madison Run	X	X	X	X	X	X	X	X	X	X		X	
Meadow Run	X	X	X	X	X	X	X		X	X		X	
Moormans River, N. Fork	X	X	X	X	X	X	X	X	X	X		X	
Naked Creek, E. Branch		X	X	X	X	X	X	X		X		X	
Naked Creek, W. Branch		X	X	X	X	X	X	X					
Onemile Run	X	X	X	X	X	X	X	X		X	X	X	
Overall Run		X	X	X			X	X					
Paine Run	X	X	X	X	X	X	X	X	X	X	X	X	X
Pass Run	X	X	X	X	X	X	X	X	X	X	X	X	
Piney River	X	X	X	X	X	X	X	X	X	X	X	X	X
Rapidan River	X	X	X	X	X	X	X	X		X		X	
Rose River	X	X	X	X	X	X	X	X	X	X	X	X	X
Sawmill Run	X	X	X	X	X	X	X	X	X	X		X	
South River		X	X	X	X	X	X	X					
Staunton River	X	X	X	X	X	X	X	X	X	X	X	X	
Swift Run		X	X		X	X	X	X				X	X
Thornton River, N. Fork		X	X		X	X	X	X		X			
Thornton River, S. Fork		X	X	X	X	X	X	X	X	X		X	
Twomile Run	X	X	X	X	X	X	X	X	X	X	X	X	X
Whiteoak Canyon Run	X	X	X	X	X	X	X	X	X	X	X	X	
Whiteoak Run	X	X	X	X	X	X	X	X		X		X	
Summary	23	42	43	35	41	40	43	38	17	33	14	33	7

Table II-3. Continued.										
Stream Name	Families of Order									
	Coleoptera									Collembola
	Dryopidae	Dytiscidae	Elmidae	Gyrinidae	Halipidae	Helophoridae	Hydrophilidae	Psephenidae	Ptilodactylidae	(Family not available)
Big Meadows Effluent								X		
Big Run	X		X					X		X
Bolton Branch	X		X					X	X	
Broad Hollow Run			X					X		X
Brokenback Run	X		X					X		X
Cedar Run			X					X		
Deep Run			X					X		
Doyles River			X					X		
Dry Run, N. Fork			X					X		X
Eppert Hollow Run								X		
Fultz Run			X					X		
Hannah Run			X					X		
Happy Creek	X		X					X		
Hawksbill Creek (Beldor)			X					X		
Hazel River	X		X					X	X	X
Hughes River			X					X		
Ivy Creek	X		X					X		X
Jeremy's Run	X		X					X		X
Keyser Run			X					X		
Land's Run	X		X					X		X
Little Hawksbill Creek			X					X		
Lower Lewis Run			X					X		X
Madison Run	X		X				X	X		X
Meadow Run			X					X		X
Moormans River, N. Fork	X		X					X		X
Naked Creek, E. Branch			X					X		
Naked Creek, W. Branch			X			X		X		
Onemile Run			X					X		X
Overall Run								X		
Paine Run	X	X	X					X		X
Pass Run	X		X					X		
Piney River	X	X	X				X	X	X	X
Rapidan River	X		X				X	X		
Rose River	X		X			X		X		X
Sawmill Run	X		X					X		
South River			X					X		
Staunton River	X		X		X			X		X
Swift Run			X					X		
Thornton River, N. Fork			X					X		X
Thornton River, S. Fork			X					X	X	
Twomile Run	X	X	X				X	X		X
Whiteoak Canyon Run	X		X	X		X	X	X		X
Whiteoak Run	X	X	X				X	X		X
Summary	20	4	40	1	1	3	6	43	4	21

students. There are seven principal rock types that form the bedrock of the area, as described by Shenandoah National Park (1998b) and shown in Figure II-4. There are granitic rocks, known as Old Rag Granite and the Pedlar Formation, which exceed one billion years in age. They cover about 8% and 25% of the park area, respectively. The plutonic rocks of these two formations are among the oldest exposed rocks in the Appalachian Mountains. Old Rag Granite is a coarsely crystalline resistant granite. The Pedlar Formation is a medium-grained granodiorite that has gneissic foliation and is found mainly in the northern portion of the park (Gathright 1976). The Swift Run Formation is a conglomerate of debris from granitic rocks and the volcanism which laid down the Catoctin Formation. It is about 600 million years old and covers about 1% of the park. The Catoctin Formation is comprised of many layers of metamorphosed volcanic rocks, which were derived from a series of volcanic eruptions that began about 600 million years ago, with decades or centuries between flows. There are at least 12 of these layers remaining in the park. Many of the cliff faces that are found in the park occur along the boundaries of this formation, including nearly all of the numerous waterfalls. The Catoctin rocks dominate the central and northern park sections and cover about 38% of the park. Dense greenstone, which formed from lava, makes up much of the Catoctin Formation and underlies most of the high ridges, interlayered with thin bands of slate or phyllite. The latter formed from ash and tuff deposited by volcanic eruptions (Gathright 1976).

The other three rock types found in SHEN are metamorphosed sedimentary rocks, about 500 million years old. These rock formations were formed when the area was covered by a large sea. The Weverton, Hampton, and Erwin members of the Chilhowee Formation are exposed along western slopes in the southern portions of the park. The Hampton Member is the most extensive, covering about 17% of the park. It is a thick deposit (~ 600 m) of phyllite and shale in the lower sections and interbedded metasandstone and phyllite with intermittent quartzite in the upper sections. The Weverton Member, a sequence of interbedded quartzite, phyllite, and metasandstone, is of limited distribution in the park.

The Antietam Formation is extremely resistant and composed of light gray quartzite and quartz-rich clastics, which may be sparsely interbedded with less resistant metasandstone and phyllite. This 200 to 300 m thick formation is visible as quartzite ledges and sharp peaks in the southwestern part of the park (Lynch and Dise 1985).

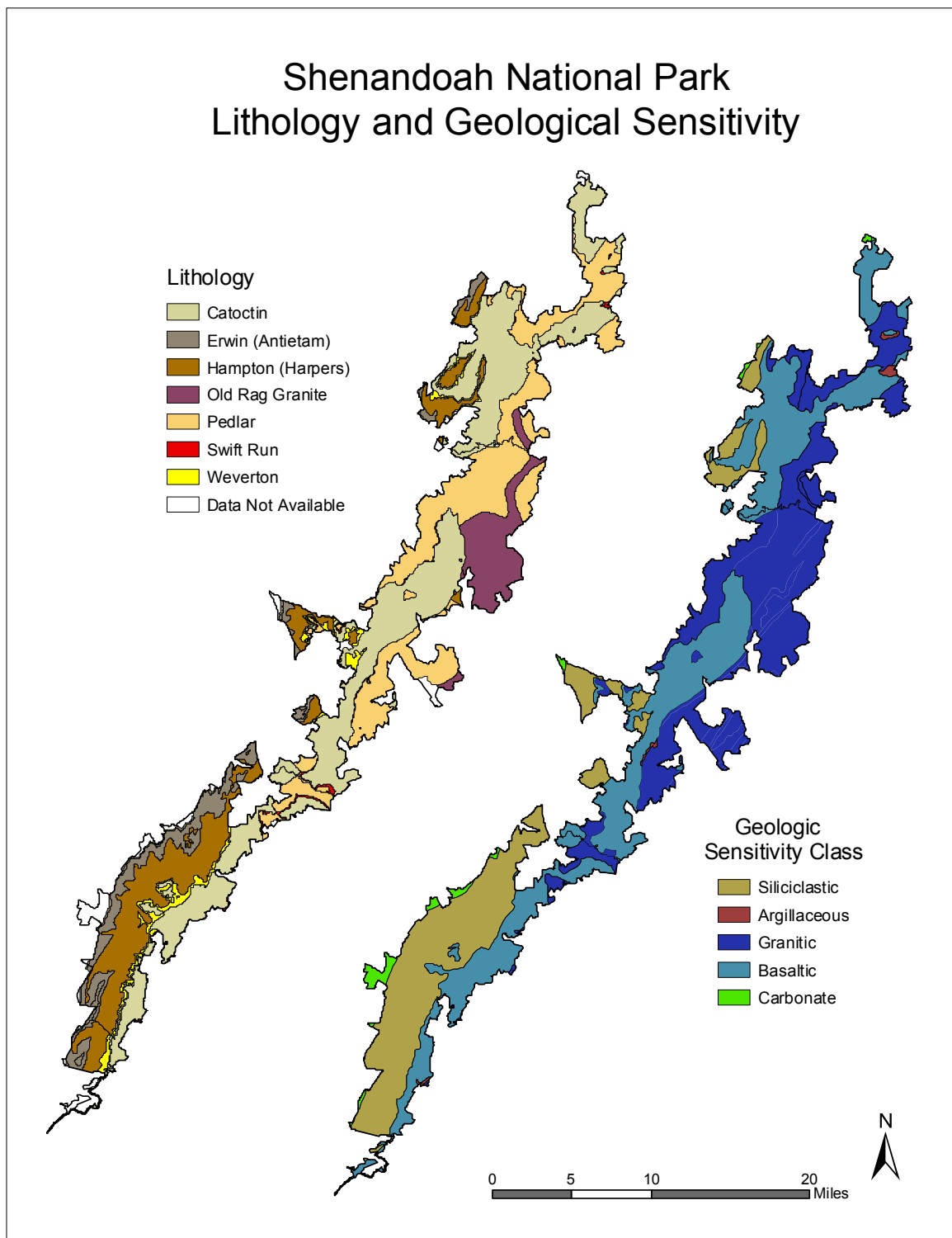


Figure II-4. Lithologic and geological sensitivity maps of SHEN. Lithology was taken from Gathright (1976). Geologic sensitivity classes are arranged in the legend from most (siliciclastic) to least (carbonate) sensitive to acidification. They can be derived from the lithological coverage as follows: siliciclastic (Erwin, Hampton, Weverton), granitic (Old Rag Granite, Pedlar, Swift Run), basaltic (Catoctin).

The geologic formations that are exposed within the park can be classified into three basic types of rock: granitic, basaltic, and siliciclastic (sedimentary rocks that contain abundant silica or sand). Siliciclastic rock types are most sensitive to acidification, followed by granitic rock types. Basaltic rock types are relatively insensitive. Each type covers approximately one-third of the park (Figure II-4). There are also minor amounts of argillaceous and carbonate rock types.

Sedimentary rocks in the park include sandstone, conglomerate phyllite, and quartzite. They are found mostly in the southern portion of the park and in a small area north of Thornton Gap. These siliciclastic rocks were deposited by streams, rivers, lakes, and the ocean. The granites are coarse-grained, crystalline rocks that contain quartz, feldspar, and small amounts of dark iron-bearing minerals, including pyroxine, hornblende, and biotite. Granitic rocks in the park include granite, granodiorite, and gneiss. These rocks are found in the Pedlar Formation and on Old Rag Mountain in the Old Rag Granite Formation. The granites and gneisses are between 1 and 1.2 billion years old and underlie other rock types. These rocks were part of a mountain range, that eroded long ago, called the Grenville Mountains, which once extended from Texas to Newfoundland (Badger 1999). Green volcanic rocks of the Catoclin Formation formed many outcrops. These green rocks were once basalts that metamorphosed into metabasalt called greenstones, which contain chlorite, epidote, and albite.

Furman et al. (1998) examined bedrock weathering properties for North Fork Dry Run, White Oak Run, and Deep Run watersheds in SHEN, using mass balance calculations. The North Fork Dry Run watershed is underlain by Precambrian granodiorite of the Pedlar Formation, with basalt dikes. White Oak Run has the Hampton and Weverton Members of the Chilhowee Formation as bedrock, and Deep Run has the Erwin and Hampton Members as bedrock. The calculations suggested that plagioclase feldspar is the dominant reactant in the granodiorite watershed, but the basalt dikes make significant contributions to the base cation budget even though they comprise a small fraction of the bedrock coverage. Calculations for the metamorphosed sedimentary watersheds suggested contributions from plagioclase feldspar, muscovite, and biotite.

The distribution of soil types in Virginia is closely related to bedrock distribution (USDA 1979). The region has not been glaciated and the typically rocky and patchy soils of the mountainous areas have formed in residual or colluvial material. Soils tend to be thin (< 2 m) and primarily classified as Ultisols and Inceptisols. Ultisols have formed from crystalline

bedrock materials along the crest and eastern flank of the Blue Ridge Province, whereas Inceptisols have formed from the sedimentary bedrock on the western flank of the Blue Ridge Province and on the ridges of the Ridge and Valley Province. All of these soils tend to be < 2 m in depth and skeletal, with a high percentage of rock fragments (Cosby et al. 1991). Depth to bedrock and extent of rock fragments are controlled mainly by slope position and orientation. The Inceptisols tend to have lower quantities of adsorbed base cations (Cosby et al. 1991).

Soils in SHEN are derived from *in-situ* weathering of bedrock or transport of weathered material from upslope positions (Elder and Pettry 1975, Carter 1961, Hockman et al. 1979, Lynch and Dise 1985). Soils characteristics therefore often reflect the underlying bedrock characteristics. The predominant soil associations include the Myersville-Catoctin, Porters-Halewood, Lew-Cataska-Harleton, and Hazleton-Drall. Colluvial fans, talus deposits, and exposed rock are also common. Soils of the park are generally classified as well-drained and medium to very strongly acidic (Lynch and Dise 1985). Soil chemistry was studied in the southwestern part of the park by Shaffer (1982). These soils tend to be thin, highly acidic, sandy loams to clay loams, derived from the Hampton and Antietam bedrock. They exhibit low cation exchange capacity (CEC; ~ 10 µeq/100 g) in the A and B horizons, low organic matter, and very low base saturation (~ 4 to 5%). The latter reflects the low weathering of the bedrock (Shaffer 1982, Lynch and Dise 1985) and to some extent might also reflect past base cation leaching in response to sulfur deposition.

In 2000, University of Virginia scientists collected and analyzed soil samples at 79 sites within SHEN in support of the acidic deposition component of this assessment. These soil samples have been archived at the University of Virginia. The samples were collected from 14 different watersheds, 5 each on primarily siliclastic and basaltic bedrock and 4 primarily on granitic bedrock. Between four and eight soil pits were excavated within each watershed, distributed across each watershed to account for differences in slope, aspect, land use history, fire history, and forest cover type. Laboratory analyses were conducted by Penn State University and Virginia Tech (Welsch et al. 2001).

The soils within watersheds situated primarily on siliclastic bedrock generally showed the lowest soil pH (median 4.4 to 4.5), CEC (median 3.5 to 7.5 cmol/kg), and base saturation (median 8 to 12%). Values for watersheds having soils primarily on granitic bedrock were generally intermediate, and basaltic watersheds were higher in all three parameters (Table II-4).

Table II-4. Interquartile distribution of pH, cation exchange capacity (CEC), and percent base saturation for soil samples ^a collected in SHEN study watersheds during the 2000 soil survey.											
Site ID	Watershed	n	pH			CEC (cmol/kg)			Percent Base Saturation		
			25th	Med	75th	25th	Med	75th	25th	Med	75th
Siliciclastic Bedrock Class ^b											
VT35	Paine Run	6	4.4	4.5	4.7	3.7	5.7	5.7	7.1	10.0	24.9
WOR1	White Oak Run	6	4.3	4.4	4.4	4.8	7.5	7.8	5.3	7.5	8.5
DR01	Deep Run	5	4.3	4.4	4.5	3.9	5.0	5.8	7.2	8.9	10.8
VT36	Meadow Run	6	4.4	4.4	4.5	3.1	3.5	7.6	7.8	8.7	11.3
VT53	Twomile Run	5	4.3	4.5	4.5	4.6	6.0	6.9	11.7	12.3	13.6
Granitic Bedrock Class											
VT59	Staunton River	6	4.7	4.8	4.9	6.5	7.5	9.2	9.1	13.9	29.5
NFDR	NF of Dry Run	5	4.4	4.5	4.7	7.3	8.0	9.2	7.5	10.8	12.4
VT58	Brokenback Run	5	4.6	4.7	4.7	7.3	8.4	9.6	6.0	6.7	9.7
VT62	Hazel River	4	4.5	4.7	4.8	5.3	5.3	6.5	12.3	12.8	21.6
Basaltic Bedrock Class											
VT60	Piney River	6	4.7	5.0	5.3	7.3	7.7	10.0	17.0	24.0	57.0
VT66	Rose River	8	4.8	5.0	5.3	7.3	10.1	10.7	19.1	38.0	63.5
VT75	White Oak Canyon	6	4.9	5.1	5.5	7.1	7.5	9.3	15.6	32.8	43.4
VT61	NF of Thornton River	7	5.1	5.2	5.3	7.7	9.6	10.8	35.6	54.4	71.2
VT51	Jeremys Run	4	4.7	5.0	5.3	6.3	7.6	7.7	15.0	22.8	46.1
^a Samples collected from mineral soil >20cm depth											
^b Watersheds are stratified according to the predominant bedrock class present in each watershed.											

Streamwater ANC, base cation, and silica concentrations vary in predictable ways in the streams of SHEN, depending on the characteristics of the underlying soils and bedrock (Lynch and Dise 1985). Each of the predominant rock formations, and its associated soils, is characterized by a particular set of minerals that control the chemical composition of drainage water.

Sullivan et al. (2002a) found that there were three soils types in the Southern Appalachian region that were associated with high percentages of acidic streams and streams having low ANC. All three of these soils types (Wallen-DeKalb-Drypond, Moomaw-Jefferson-Alonzville, and Shottower- Laidig-Weikert) are present within SHEN. For the Southern Appalachian Mountains Initiative (SAMI) assessment, each of these soil types was characterized by over 25% of sampled streams having $\text{ANC} \leq 20 \mu\text{eq/L}$. Within SHEN, these soil types are most common in the South District, but are found within all districts along the western slope of the mountains, throughout the length of the park (Figure II-5). The Waller-DeKalb-Drypond type is the most common of the three within SHEN, and is the most prevalent soil type along the western slope within the park.

G. VEGETATION

The distribution of forest vegetation in the park (shown in Figure II-6) and surrounding region is largely determined by moisture availability, which in turn is strongly influenced by soil and bedrock characteristics and topographic features (Hack and Goodlett 1960, Edmunds et al. 1986). The Ultisols tend to have greater moisture holding capacity and are frequently dominated by red oak (*Quercus rubra*), maple (*Acer* spp.), yellow poplar (*Liriodendron tulipifera*), hemlock (*Tsuga canadensis*), rhododendron (*Rhododendron maximum*), and other moisture demanding species. Forests associated with the Inceptisols are more commonly dominated by chestnut oak (*Quercus prinus*), Virginia pine (*Pinus virginiana*), azalea (*Rhododendron calendulaceum*) and other dry habitat species (Cosby et al. 1991).

The park is located in a transitional area between northern and southern vegetation types. Higher elevations of the park and north-facing slopes tend to be dominated by northern species whereas lower elevations and south and west facing slopes are covered by central hardwood forests. There are seven primary vegetation types within the park. The chestnut oak forest type is common on the low to mid elevation drier slopes, which often have southern or southwestern exposure. This forest type is dominated by chestnut oak, with red oak as its primary associate. The second most common forest type in the park is yellow poplar. It is most frequently found on lower slopes of the more moist drainages in the north and central districts of the park, especially on north and east facing slopes. Yellow birch (*Betula alleghaniensis*), hemlock, white pine (*Pinus strobus*), and white oak (*Quercus alba*) are common associates. Cove hardwood is the third most common forest type, and is comprised of ash (*Fraxinus* sp.), red oak, and basswood

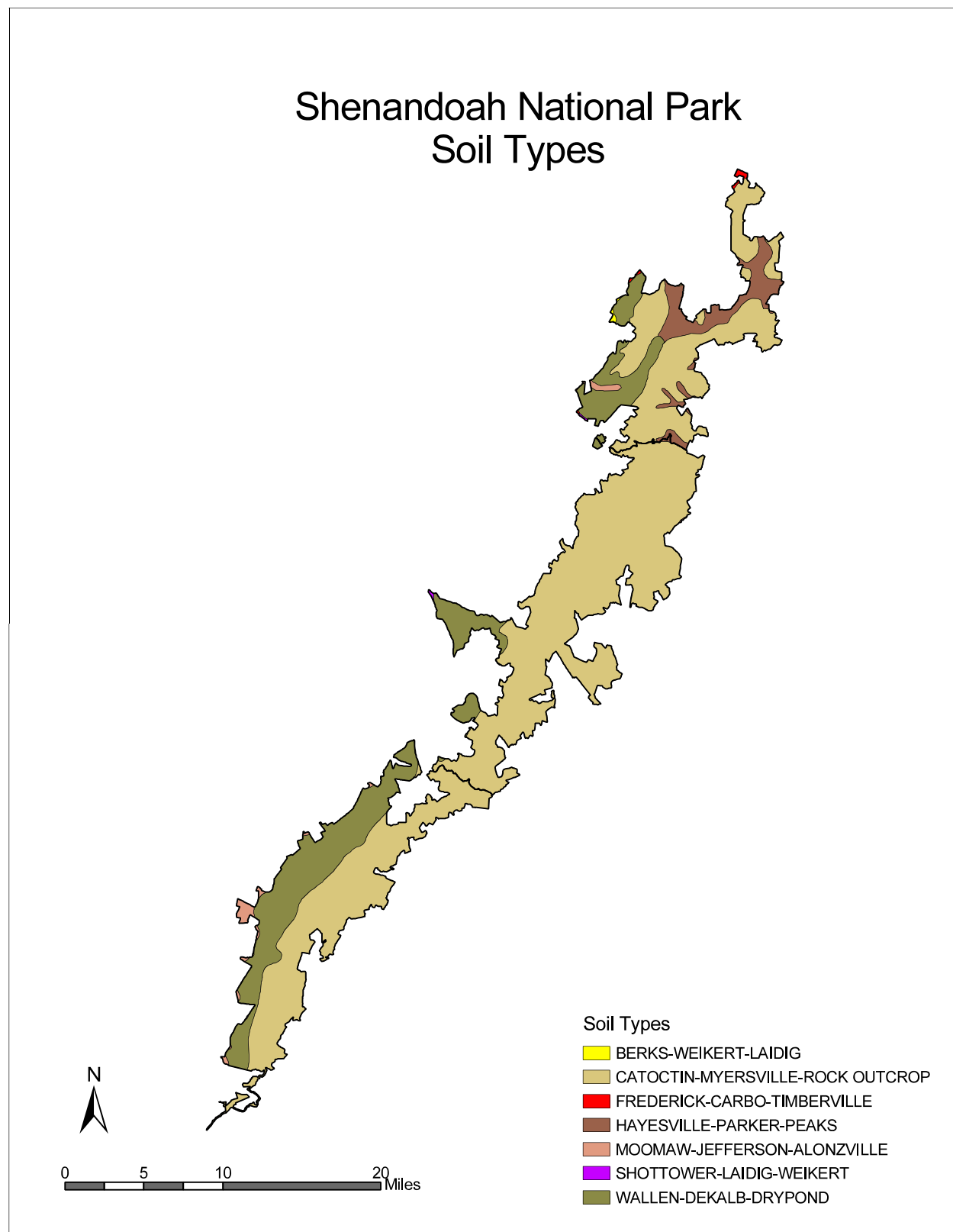


Figure II-5. Soils types in SHEN. All soil types in the legend are present within the park, but several are present only in very small areas.

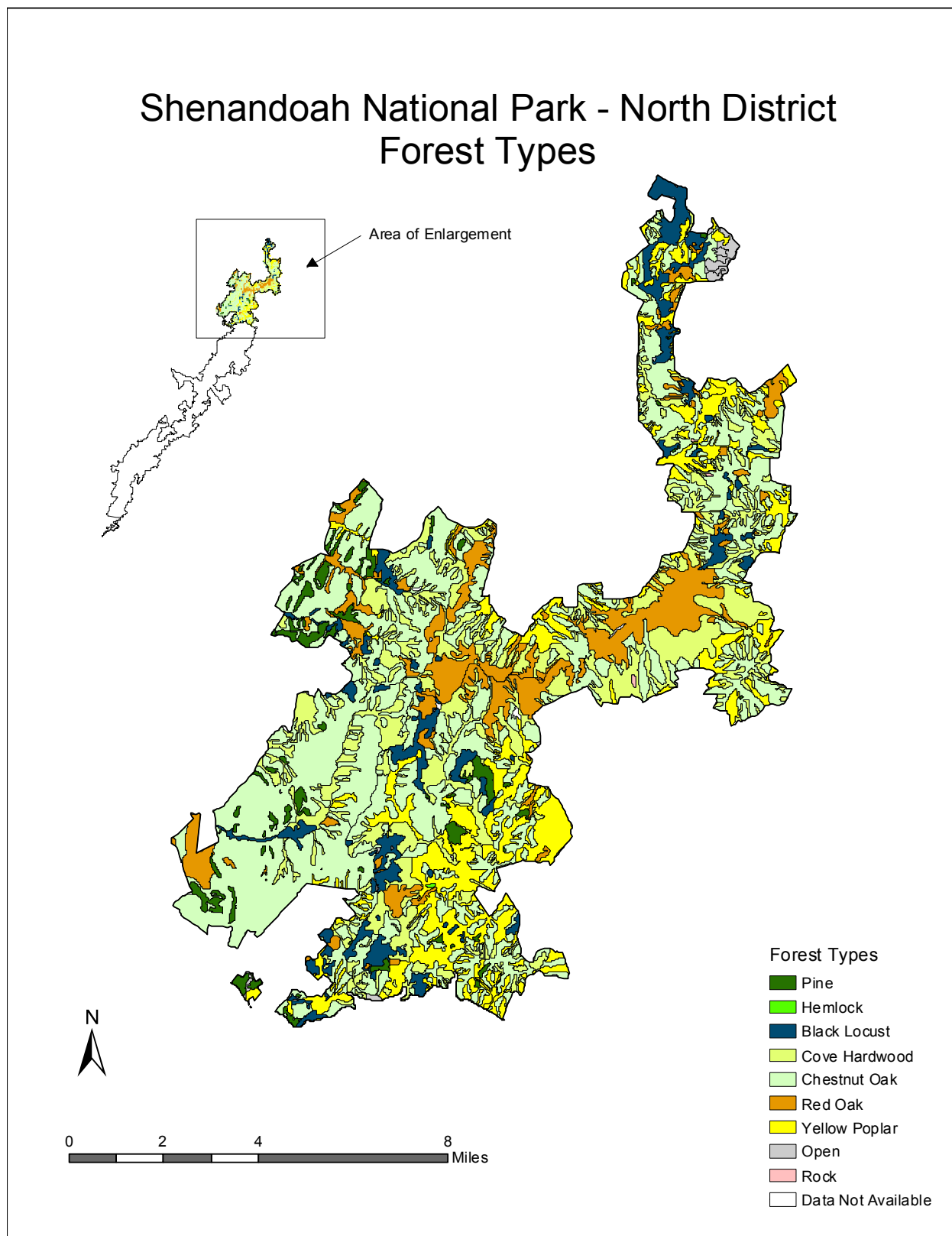


Figure II-6. Major forest types within SHEN, by district: A) North, B) Central, C) South.

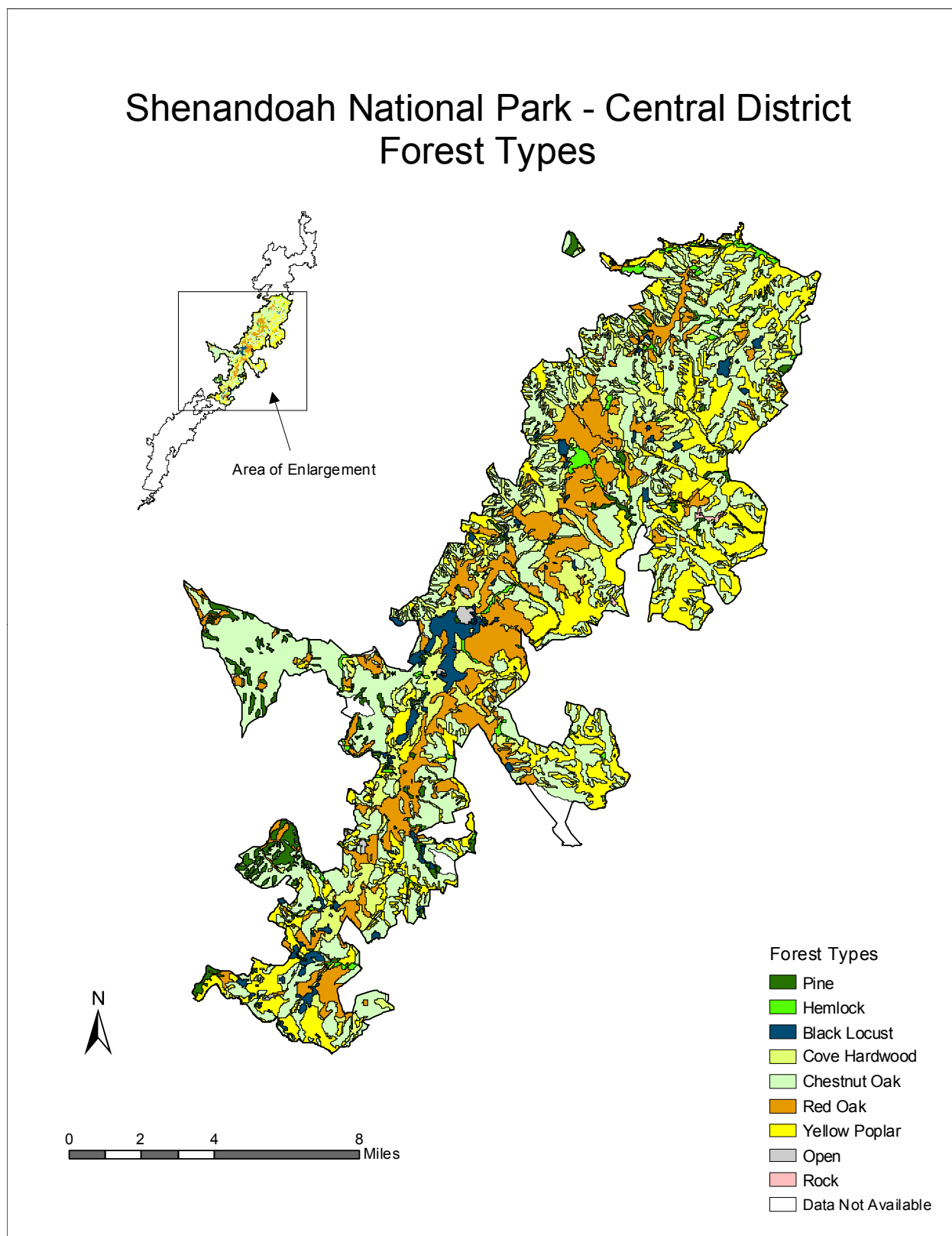


Figure II-6. Continued.

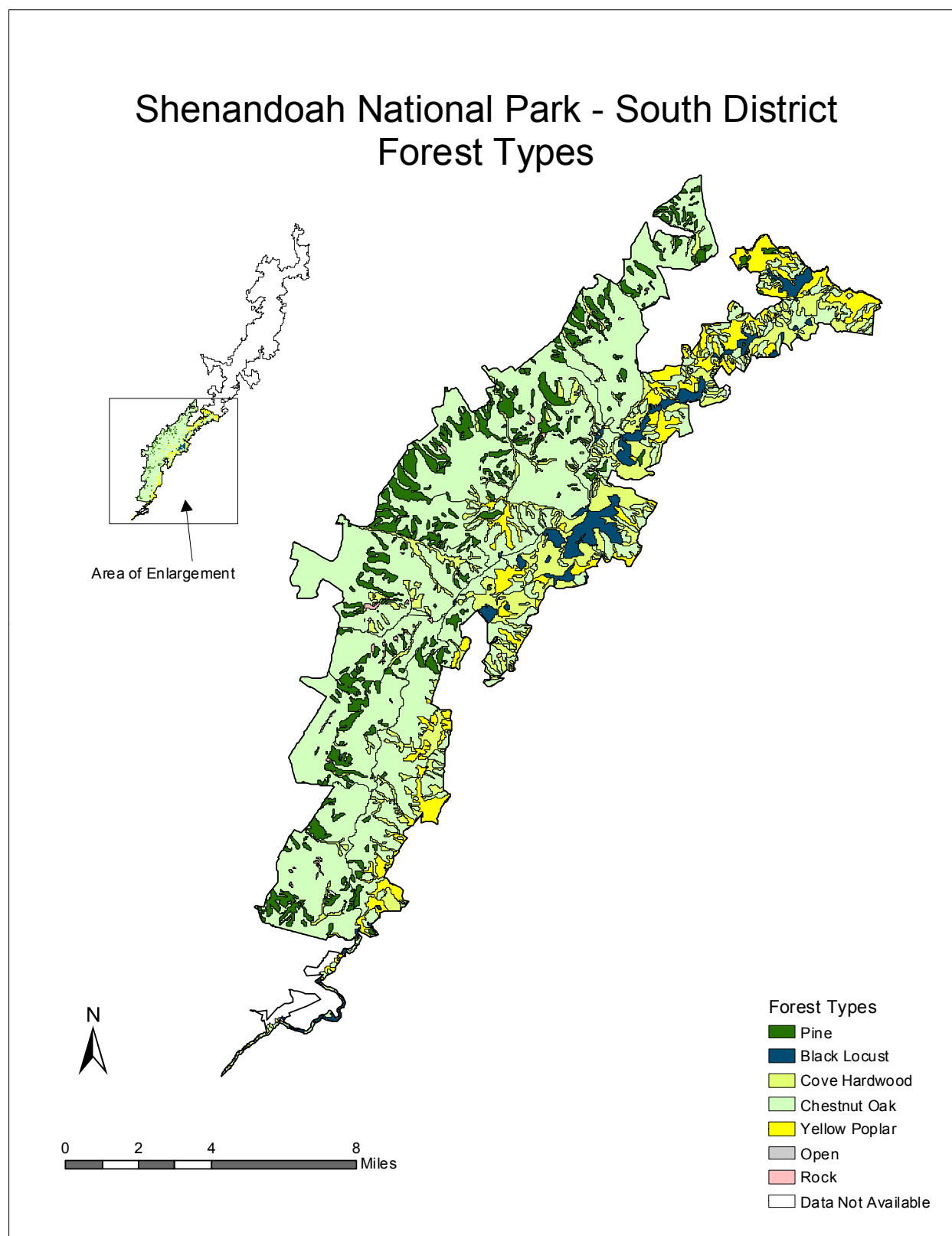


Figure II-6. Continued.

(*Tilia americana*). It is located mostly on moist sites in the hollows and along stream drainages. The red oak forest type is found over a fairly broad range of environmental conditions. It occupies the most mesic ridgetops and side slopes. Red oak is dominant in this forest type, which also includes mockernut hickory (*Carya tomentosa*), pignut hickory (*C. glabra*), chestnut oak, and white oak. The pine forest type includes eastern white pine (*Pinus strobus*), Virginia pine, and pitch pine (*P. rigida*). These species are primarily successional and are found on previously disturbed sites. Black locust (*Robinia pseudoacacia*) is an early successional forest type that is found in recently disturbed areas. It also includes black cherry (*Prunus serotina*), tree of heaven (*Ailanthus altissima*), and Virginia pine. Moist sites in association with spring seeps, streams, north facing slopes, and shaded drainage bottoms are often covered with hemlock forests, which occur in pure stands.

Big Meadows is a large (48 ha) high-elevation grass/shrub plant community that was maintained as a meadow in historic times by grazing and burning, and later by burning and mowing. A small bog occurs in its northeast corner, where many plant species are found that do not occur elsewhere in the park.

Limberlost is a high-elevation area of seeps and springs that contains an extensive old growth stand of eastern hemlock and red spruce (*Picea rubens*). The area also contains speckled alder (*Alnus rugosa*), Canada yew (*Taxus canadensis*), and the only occurrence in Virginia of alder-leaved buckthorn (*Rhamnus alnifolia*).

Cliffs and rocky north- and west-facing slopes support fragile populations of plants, including some boreal species such as balsam fir (*Abies balsamea*), mountain sandwort (*Minuartia groenlandica*), and bearberry (*Arctostaphylos uva-ursi*) at the tops of the highest peaks (e.g., Hawksbill, Stony Man and Old Rag). Crescent Rock, Black Rock, Hawksbill Summit, Stony Man Summit, and Old Rag Summit face prevailing winds and include heaths such as minnie bush (*Menziesia pilosa*) and northern bush honeysuckle (*Diervilla lonicera*), and crevice plants such as Allegheny stonecrop (*Sedum telephioides*), Michaux's saxifrage (*Saxifrage michauxii*), and three-toothed cinquefoil (*Potentilla tridentata*).

H. WILDLIFE

Explorers to the Shenandoah Valley and Blue Ridge Mountains in the early 1700s reported an abundance and variety of animals, some of which have since been extirpated. Woodland bison (*Bison bison*), the largest of Shenandoah's original fauna, inhabited the valleys and low-

elevation foothills with one documented trail crossing the Blue Ridge at Rockfish Gap. Eastern elk (*Cervus canadensis*) originally occurred throughout the entire northern Shenandoah Valley, including surrounding ridges. Timber wolves (*Canis lupus*) and mountain lions (*Felis concolor*) were also among the region's original inhabitants and together with the black bear (*Ursus americanus*), constituted the primary predators of large mammal species. As European settlers cleared the land, introduced exotic species, and hunted native animals, both the abundance and variety of wildlife decreased, with total elimination of some species. However, since the establishment of the park, some species have been reintroduced and some have naturally reestablished. Currently, the park sustains populations of white tailed deer (*Odocoileus virginianus*), black bear, bobcat (*Lynx rufus*), opossum (*Didelphis virginiana*), racoon (*Procyon lotor*), skunk (*Mephitis mephitis*), gray fox (*Urocyon cinereoargenteus*), and eastern cottontail (*Sylvilagus floridanus*; Shenandoah National Park 1993). There are over 200 species of resident and transient birds known to use the park's habitats, including turkey (*Meleagris gallopavo*). Sixty-one species of reptiles and amphibians have been recorded within the park. The Shenandoah salamander (*Plethodon shenandoah*) was listed as an endangered species in 1989. Its range is very limited and includes four areas located in the park at high elevation on rocky talus slopes (Shenandoah National Park 1998b).

I. DISTURBANCE

The forests of SHEN exist in an environment that includes insects and pathogens, competition and plant community dynamics, and abiotic factors, including air pollutants and disturbance. To understand how terrestrial ecosystems respond to air pollution requires an understanding of how plants normally grow in a stressful environment, in addition to the details of their response to pollutants and potential alterations in normal growth.

Forests make difficult experimental subjects. Plants grow in a variety of soils, in populations of mixed sizes and species, and under variable climatic conditions. Forests in national parks are even less amenable to experimentation—they are to be protected, studied, and enjoyed, not instrumented, poked, and prodded. On the other hand, it is important to understand how anthropogenic stresses affect the health and vigor of the forest.

SHEN comprises one of the nation's most diverse botanical reserves. The documented flora of the park includes over 1,400 species of plants. From the 1720s to the establishment of the park, much of the area was cleared. The invasion of non-native insects and pathogens during the

20th century seriously impacted the vegetation communities of the park. The chestnut blight (*Endothia parasitica*), a canker disease which kills American chestnuts (*Castanea dentata*), entered the United States in the early part of the 20th century. The disease spread quickly throughout the eastern United States. All chestnut trees in the park were affected by this disease. By about 1940, only remnant chestnut sprout growth existed. The loss of this tree species had a large impact on the structure and composition of park forests because some stands had contained 50% or greater numbers of chestnuts.

The gypsy moth (*Lymantria dispar*), which was introduced into the United States in the 1860s, began to impact the forests of the park in 1986. Because the preferred food of gypsy moths is oak, the forests of the park which were predominantly oak were vulnerable to widespread impact. Initial effects included defoliation of oaks, with as much as 16,000 ha defoliated in 1989 alone. Repeated defoliations, coupled with several years of drought, caused widespread oak mortality in the late 1980s and early 1990s. An introduced fungus (*Entomophaga maimaiga*), which attacks gypsy moths, reduced gypsy moth populations in the early 1990s. By 1996, effects on the forest canopies of the park were dramatically curtailed. The non-native hemlock woolly adelgid (*Adelges tsuga*) and the native southern pine beetle (*Dendroctonus frontalis*) have also had dramatic impacts on park forests.

Based on records kept since 1935, the park has approximately eight naturally-occurring fires per year. These fires tend to remain small, and are easily suppressed except during times of drought. Large fires within the park are overwhelmingly human-caused fires. The most notable of these was the Shenandoah Complex Fire, which burned 9,350 ha of park land in the fall of 2000. A fire management plan was prepared for the park (Shenandoah National Park 1993), with a primary objective of fire suppression. The plan details suppression strategies, prevention criteria, interagency cooperation, and programs to prevent adverse impacts of wildfire to life, property, and adjacent lands. In addition, increased emphasis is being directed towards prescribed fire components to determine appropriate actions regarding natural and management-ignited prescribed fires. The park is in the final review draft phase of updating its fire management plan.